

COMMON AND ALTERNATIVE APPROACHES TO DESALINATION

BY

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**WATER DESALINATION WORKSHOP
MAY 6-7, 2003
ARLINGTON, VIRGINIA**

DESALINATION TECHNOLOGIES

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 - B. SUBTERRANEAN**
 - 2. THERMAL**
 - A. EVAPORATIVE**
 - B. FREEZING**
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MECHANICAL – PRESSURE – PUMP - REVERSE OSMOSIS

MOST WIDELY USED DESALTING PROCESS AFTER MSF, \$350 MILLION BUSINESS, GROWING 12%/YR

TECHNOLOGY OF CHOICE FOR BRACKISH WATERS

BRACKISH WATER – 75 PSIG-500 PSIG; SEAWATER 750 PSIG-1200 PSIG; “UNDER THE SINK” 20 PSIG

MOSTLY COMPOSITE POLYAMIDE MEMBRANES IN SIPRAL WOUND CONFIGURATION, MODIFIED FOR SOFTENING, ALSO SOME CELLULOSE ACETATE BLENDS

KEY UNIT OPERATION IS PRETREATING THE FEEDWATER

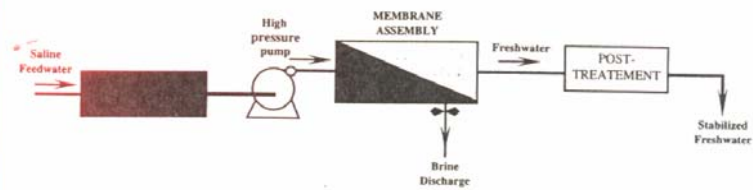
MEMBRANES CHLORINE SENSITIVE EXCEPT FOR CELLULOSE ACETATE ONES

PRODUCT: < 50 MG/L BRACKISH; <350 MG/L SEAWATER

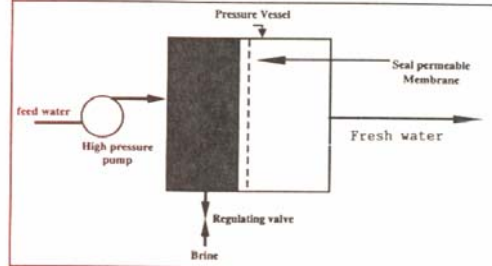
HAND PUMPS AVAILABLE FOR SMALL SHIPBOARD UNITS AND LIFEBOATS

ENERGY RECOVERY FOR SEAWATER – ENERGY USE WITH ~10 kWh/kgal, W/O ~15 kWh/kgal

FLOW DIAGRAM OF REVERSE OSMOSIS PROCESS

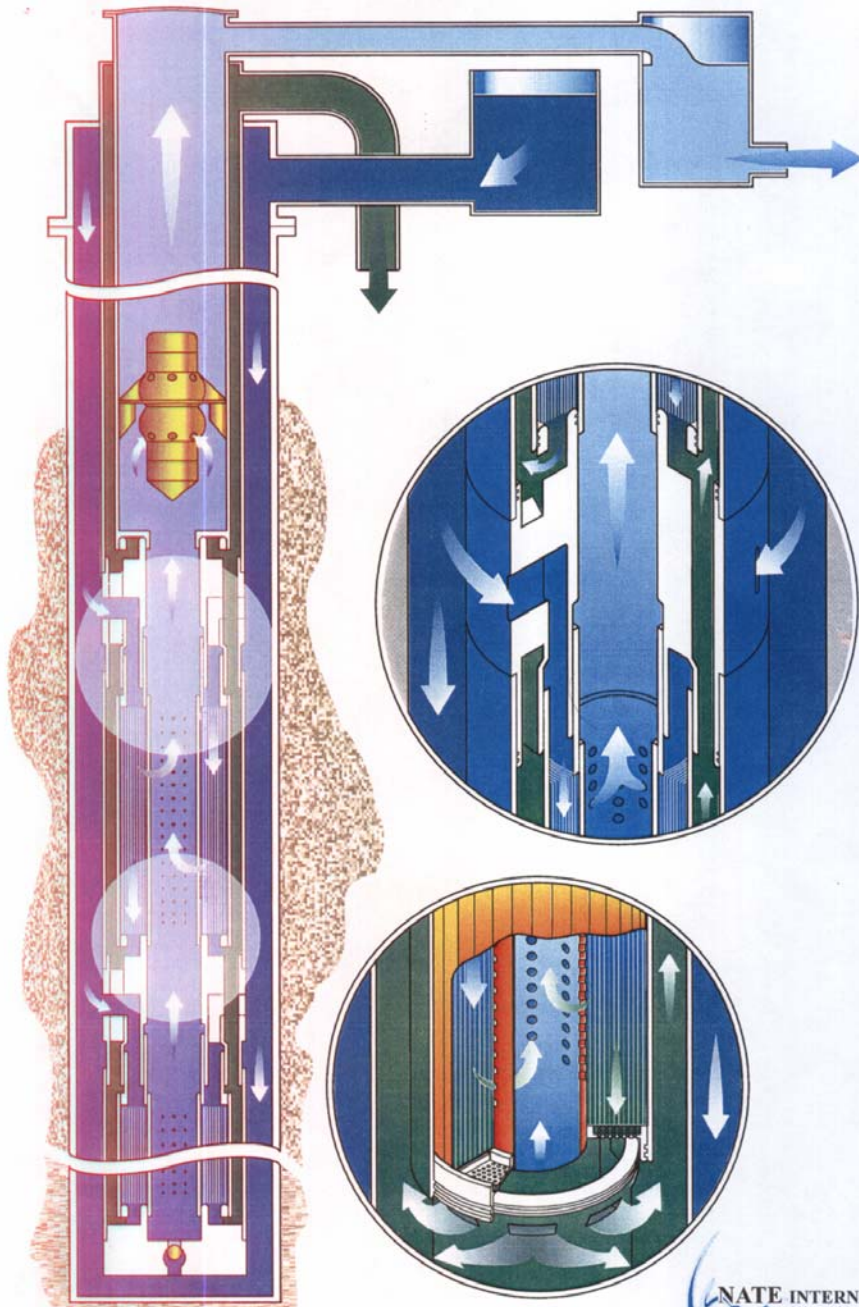


Simplified RO Flow Diagram



MECHANICAL – PRESSURE - SUBTERRANEAN

- **1000PSIG = 69 BARS = 2307 FEET OF WATER**
- **DEEP WELLS – UNDER DEVELOPMENT BY NATE INTERNATIONAL**
- **PLACING RO MODULES AT THE BOTTOM OF VERY DEEP MINES AND THEN PUMPING UP THE PRODUCT – SOUTH AFRICA**
- **RED SEA/MEDITERRANEAN SEA TO DEAD SEA RO PLANT, ALSO POWER GENERATION**



MECHANICAL – THERMAL - EVAPORATIVE

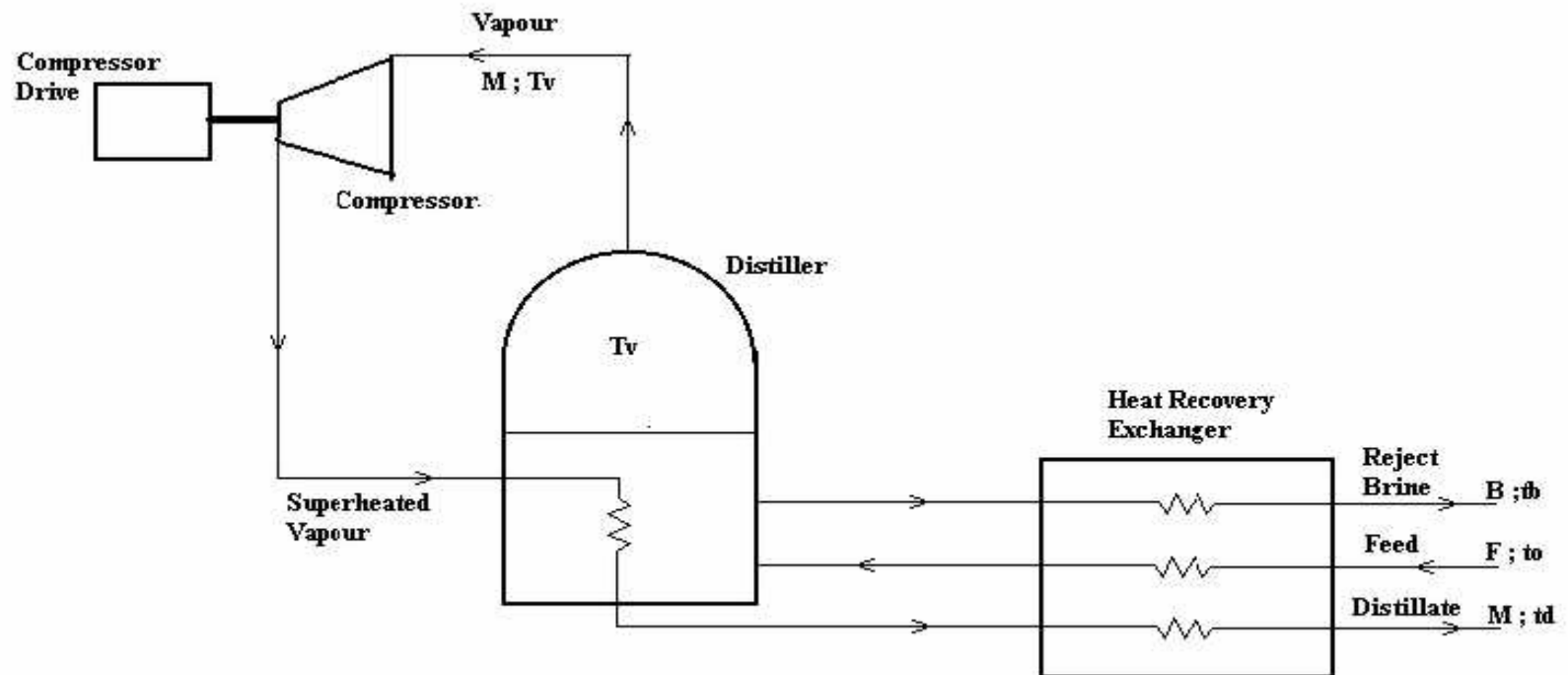
- **MULTI-STAGE FLASH (MSF) – IS THE METHOD MOST WIDELY USED ON A LARGE SCALE AND THERE IS PROBABLY LITTLE ROOM LEFT FOR ITS IMPROVEMENT EXCEPT BY USING HIGH GRADE ALLOYS TO EXTEND LIFE SPAN. CAN MAKE USE OF LOW GRADE HEAT PRODUCED DURING ELECTRICITY GENERATION THAT WOULD BE OTHERWISE WASTED, THUS CONSIDERABLE REDUCING THE ENERGY DEMANDS OF THE PROCESS. HAS THE ADVANTAGE OF MANY YEARS OF EXPERIENCE, REQUIRES PROBABLY LESS TECHNICAL EXPERTISE AND IS QUITE ROBUST. ESSENTIALLY EMPLOYED ONLY FOR SEAWATER DESALINATION. PRODUCT WATER AT LESS THAN 20 MG/L.**

MECHANICAL – THERMAL - EVAPORATIVE

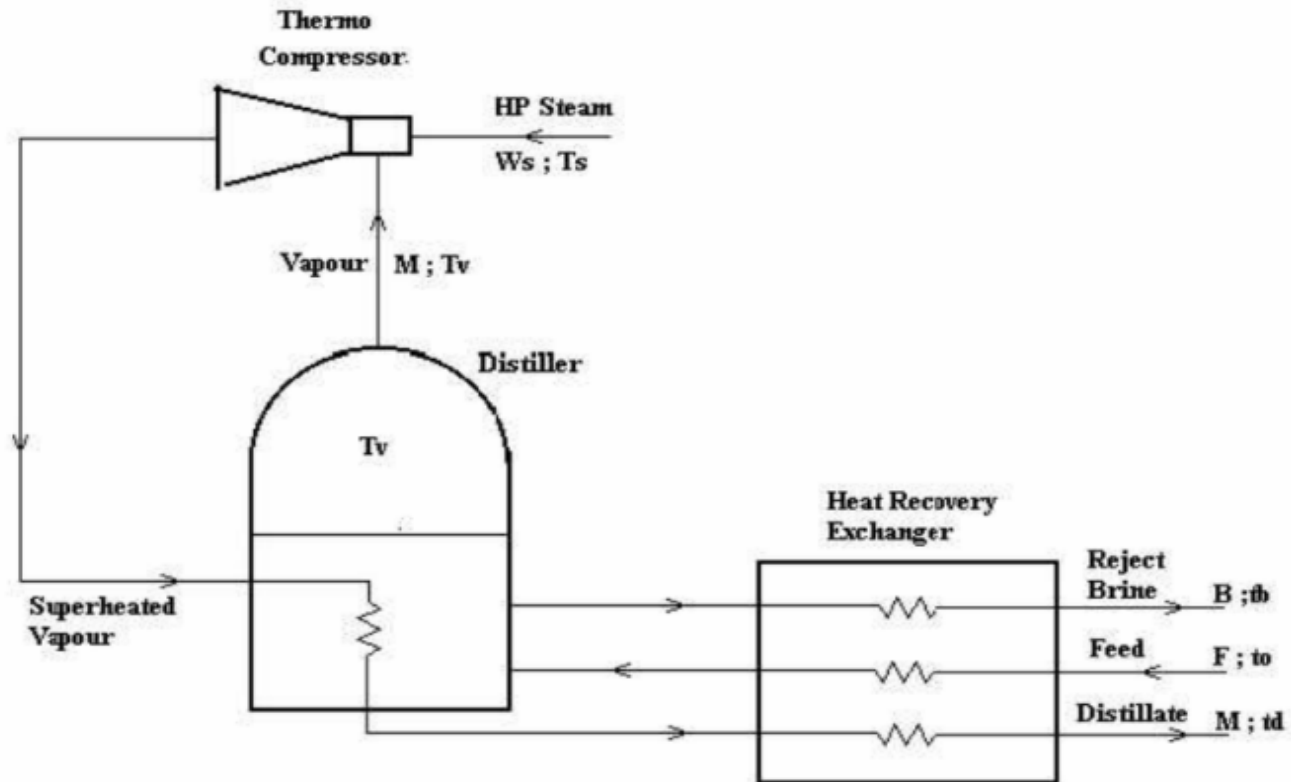
- **MULTI-EFFECT DISTILLATION (MED) – PRODUCES SIMILAR PRODUCT TO THAT OF MSF PLANTS BUT IS NOT USED AS EXTENSIVELY. HAS CERTAIN ADVANTAGES. THE PROCESS TAKES PLACE AT A LOWER TEMPERATURE THAN MSF THUS REDUCING CORROSION AND SCALING, THUS REDUCING CHEMICAL CONSUMPTION, MAINTENANCE AND CORROSION RESISTENT MATERIALS. HAS FEWER NUMBER OF STAGES, SO LESS PLANT REQUIRED. CAPACITIES ARE CONTINUING TO INCREASE- BEGINNING TO COMPETE WITH MSF.**

VAPOR COMPRESSION, MECHANICAL - THERMAL, ARE THE CHOICES FOR SMALL SCALE COMPACT PLANTS. ENERGY REQUIREMENTS ONLY SLIGHTLY ABOVE RO. PRESENT IN MOST NAVAL VESSELS, CAN BE AND IS USED FOR RAPID DEPLOYMENT – SKID MOUNTED

MECHANIAL VAPOR COMPRESSION



THERMAL VAPOR COMPRESSION



MECHANICAL – THERMAL - FREEZING

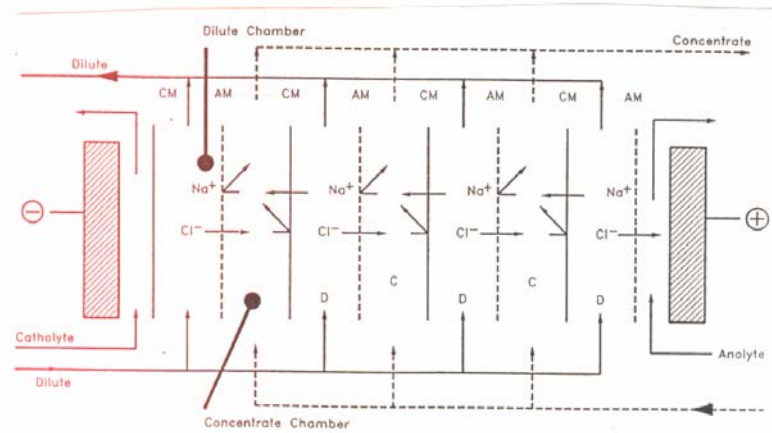
- **IT TAKES 13.5% AS MUCH ENERGY TO CONVERT WATER INTO ICE AS IT DOES TO CONVERT WATER INTO VAPOR (HEAT OF FUSION 144 BTU/LB, HEAT OF VAPORIZATION 1070 BTU/LB). MAINLY SEAWATER DESALTING**
- **DIRECT FREEZING – VACUUM FREEZING VAPOR COMPRESSION: REDUCE TEMPERATURE TO CLOSE TO FREEZING POINT, CREATE A VACUUM, RECOVER AND CONDENSE SALT FREE VAPORS, RESULTING SLURRY WASHED**
- **INDIRECT FREEZING: USES A WATER IMMISCIBLE REFRIGERANT (BUTANE), OPERATES AT HIGHER PRESSURE**
- **ABSORPTION: USES A HYGROSCOPIC MATERIAL – WATER VAPOR ABSORBED IN COLD 50% LiCl SOLUTION, HEAT APPLIED TO RELEASE WATER**
- **KEY EQUIPMENT – HEAT EXCHANGER, DEAERATOR, FREEZER, ICE WASHER, MELTER, VACUUM/COMPRESSOR (FP=BP)/ABSORBER, RECIRCULATION**
- **FREEZE-THAW CYCLES: BUILDING MOUNDS OF ICE CRYSTALS OVER HIGHLY CONCENTRATED BRINE IN NORTH DAKOTA PONDS**

MECHANICAL – THERMAL - HUMIDITY CONTROL

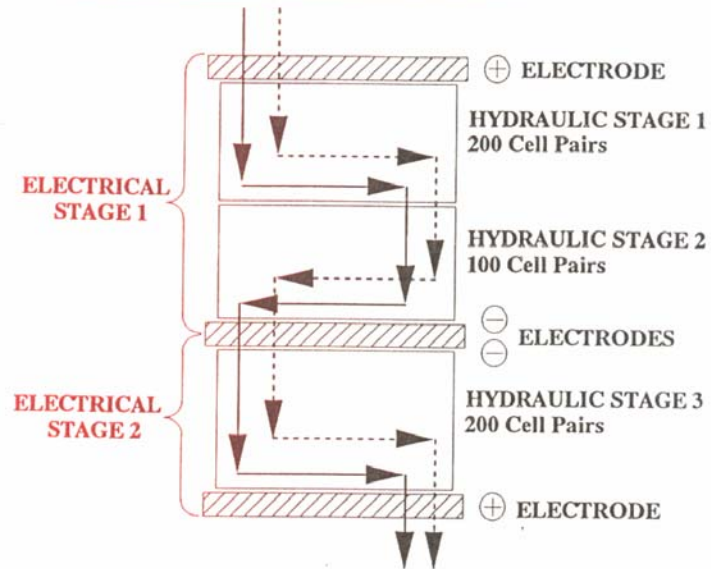
- **NO COMMERCIAL INSTALLATIONS**
- **LABORATORY CONCEPT**
- **LOCATION IN WARM COASTAL AREAS**
- **KEY EQUIPMENT PIECES – CONDENSER, REFRIGERATION, AIR BLOWER,**

ELECTRICAL – ELECTRODIALYSIS/ELECTRODIALYSIS REVERSAL

- **CATION AND ANION EXCHANGE MEMBRANES WITH ELECTRODES - ANODE AND CATHODE - AT EITHER END**
- **FLOW CHANNELS, CREATED BY SPACERS, SEPARATING MEMBRANES**
- **DC POWER SUPPLY WITH POLARITY REVERSAL**
- **LOW PRESSURE CIRCULATION PUMPS**
- **AIR BLOWER AND VENT FOR H₂ PRODUCED AT CATHODE**
- **ACID/ANTISCALANT - STAGING LIKE RO**
- **MIGRATION OF IONS SO NONIONICS (SILICA, PATHOGENS) STAY WITH PRODUCT**
- **NOT COMMERCIAL FOR HIGH TDS FEEDS – POWER REQUIREMENT TOO LARGE**



ELECTRODIALYSIS/ELECTRODIALYSIS REVERSAL



ELECTRICAL - CAPACITIVE DIONIZATION

- **LAWRENCE LIVERMORE LABOARATORY – UNDER DEVELOPMENT**
- **BASED ON USE OF “CARBON AEROGEL”**
- **USE OF STACKS SIMILAR TO ELECTRODIALYSIS**
- **DISSOLVED IONS, UNDER ELECTRICAL ATTACTION, ADSORBED ONTO AEROGEL**
- **REGENERATION OF GELS USING RINSE WATER**
- **ENERGY @ 34 kWh/kgal LESS 18.4 kWh/kgal RECOVERABLE ENERGY**

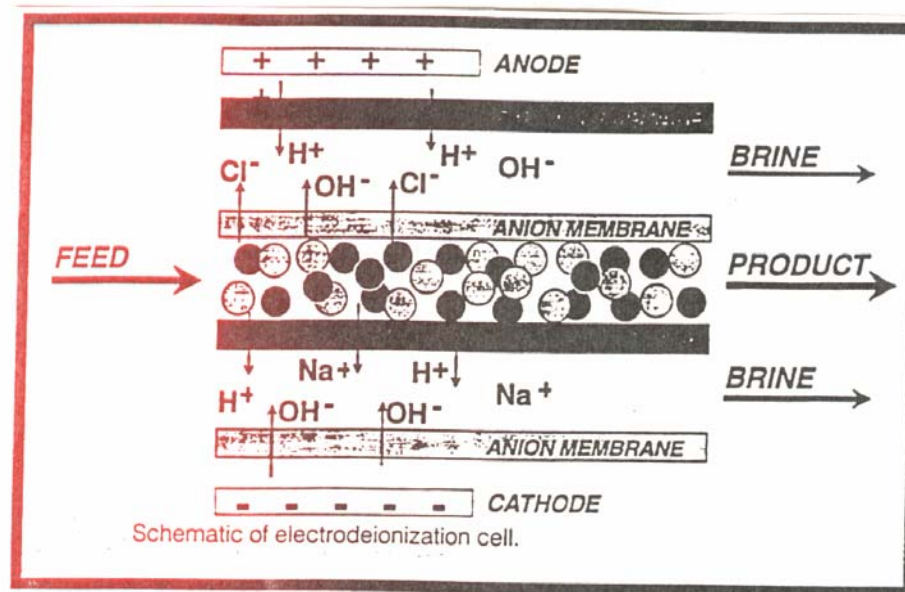
CHEMICAL – ION EXCHANGE

- **REVERSIBLE EXCHANGE OF IONS BETWEEN A SOLID (IX RESIN) AND A LIQUID, NO SUBSTANTIAL CHANGE IN STRUCTURE OF RESIN WITH USE**
- **FIXED BEDS AND CONTINUOUS COLUMNS**
- **ECONOMICS FAVOR IX OVER RO WITH FEED TDS < 125 PPM CaCO₃**
- **PRODUCT USED TO COMPLETELY DEMINERALIZE WATER**
- **NATURAL PRODUCTS (ZEOLITES), SYNTHETIC INORGANICS (ALUMINO SILICATES) AND ORGANICS (MOST OF TODAY'S RESINS) (COPOLYMER OF STYRENE AND DIVINYL BENZENE, POLYACRYLIC RESINS AND 1°, 2° AND 3° AND POSSIBLY 4° AMINES)**
- **SOLD AS GRANULES OR BEADS WITH POROSITIES ENHANCED CHEMICALLY**
- **ENVIRONMENTAL CONCERNS ON DISPOSAL OF REGENERATION CHEMICALS**

CHEMICAL – SOLVENT EXTRACTION

- **PURAQ COMPANY, STAMFORD, CONNECTICUT**
- **PHASE RELATIONSHIP BETWEEN SOLVENT, SEA WATER SALTS AND WATER**
- **SOLVENT - LIQUID POLYMER OF MW (>1200) – POLYGLYCOL TERPOLYMERS - SO THAT EQUILIBRIUM SOLUBILITY IS ESSENTIALLY ZERO BY FLORY-HUGGINS THEORY OF POLYMER SOLUTIONS**
- **WATER IS TAKEN UP BY SOLVENT POLYMER WITH SOME SALT**
- **CENTRIFUGAL SEPARATION FROM CONCENTRATED BRINE**
- **POLYMER-WATER IS WASHED WITH PRODUCT TO REMOVE DISSOLVED SALTS**
- **RAISING TEMPERATURE TO 55°F SEPARATES INTO 2 LIQUID PHASES: 1. RECYCLED AND WASH AND 2. FINAL PRODUCT**

CONTINUOUS DEIONIZATION



ELECTROMAGNETIC

“PASSING SEA WATER SOLUTION THROUGH A PERMANENT MAGNETIC FIELD INCREASES THE CONDUCTIVITY OF THE SOLUTION. SEPARATION SALT FROM WATER, APPLYING REVERSE OSMOSIS TECHNIQUE, SHOWED THAT LOWER SALT PASSAGE IS FOUND FOR THE MAGNETICALLY TREATED SOLUTIONS COMPARED TO THAT FOR THE UNTREATED ONES. THERE, IT IS BELIVED FROM THE GIVEN FINDINGS THAT THE MAGNETIC FIELD MAY CAUSE PHYSICAL CHANGES TO THE NATURE OF THE SEA WATER SOLUTION WHEN IT IS RECIRCULATED FOR A CERTAIN TIME IN A MAGNETIC FIELD.” HALTHAM AL-QAHTANI, UNIVERSITY OF BAHRAIN

ULTRA-SOUND RESEARCH ??

WATER TRANSPORTATION

- **ICE BERG TOWING – ARTIC/ANTARTIC OCEANS**
- **PIPELINE – LAKE GASTON, NC TO VIRGINIA BEACH, VA**
- **TANKER – TURKEY TO ISRAEL**
EBRO RIVER TO MALLORCA SPAIN
BALLAST ON RETURN TRIP TO MIDDLE EAST
A USE INSTEAD OF SCRAPPING TANKERS
- **SEA GOING POLYETHYLENE BAGS – ALASKA PROPOSAL**